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(54) Electrosurgery system and instrument

(57) In an electrosurgery system having a radio frequency generator and an instrument with a treatment electrode, the generator includes a circuit for sensing thermionic emission from the electrode as means of controlling the supply of radio frequency power to the l ctrode. Thermionic emission is related to the electrode temperature and has a rectifying effect on the RF at the output thus allowing the appearance of a DC voltage component on the plates of the output condenser. S nsing such DC voltage is therefore a means to detect thermionic emission and electrode temperature. Such DC voltage can be detected using a detector with an isolated output, and generator output power is controlled so as to limit the DC voltage to a predetermined threshold. Accordingly, the temperature of the electrode can be limited to avoid electrode destruction. The invention also has application to reducing nerve stimulation due to electrosurgical treatment.

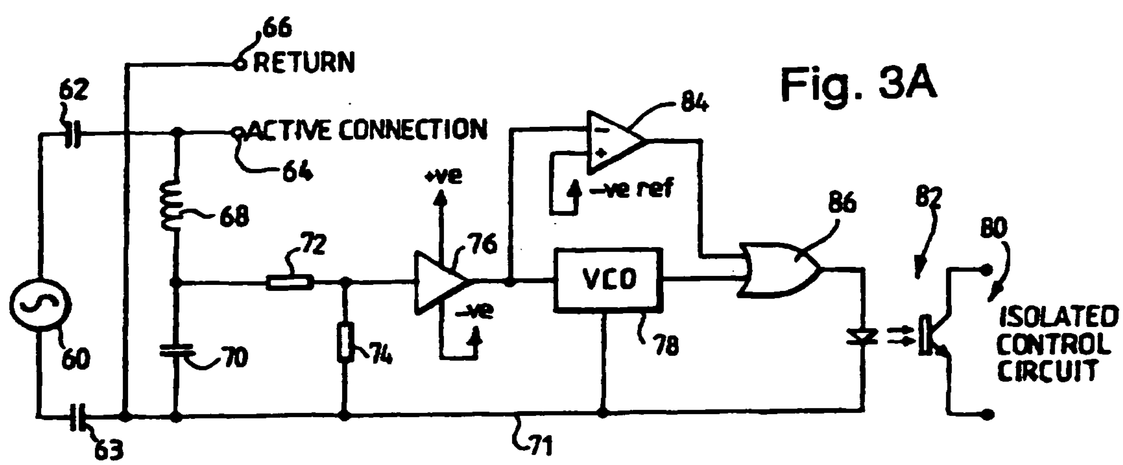

Fig. 3A

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in excess of 2 volts, and a control circuit coupled to the source for controlling the r.f. energy applied to the active output terminal in response to the d.c. offset voltage at the shunt input.

[0011] According to a third aspect of the invention, a method of performing electrosurgical tissue cutting or ablation comprises applying r.f. energy to an electrosurgical instrument so as to promote arcing at a treatment electrode of the instrument, and regulating the level of applied energy according to the d.c. voltage attained at the electrode due to thermionic emission from the electrode. The r.f. energy may be regulated to maximise the t mperature of the electrode without substantial electrod damage, typically by limiting the d.c. voltage to a threshold value of less than 100V.

[0012] In the above-described preferred embodiment, detection of the thermionic effect occurs as a r sult of the continual discharge of capacitors in the output stage of the generator through a high value resistance, the detected DC voltage across the electrodes being representative of this effect. Since this detection technique is limited by the time constant for the discharge of the capacitors in the output stage, it has the disadvantage of having a relatively slow response time. The time constant is the product of the capacitance and resistance in the circuit. The capacitors are necessarily large to reduce output impedance, and the shunt resistance connected across the output terminals is large to prevent the flow of significant direct current through the patient.

[0013] A further embodiment provides an alternative technique for detecting thermionic emission from the active electrode in which an alternating current phenomenon affected by thermionic emissions is detected, obviating the need for a DC conducting path across the output terminals of the generator. Accordingly, a further aspect of the present invention provides a modulated generator output, and a detection circuit coupled to the generator output by means of a coupling which does not include any DC conductive path, the detection circuit being tuned to the frequency of the modulation of the gen rator output, wherein thermionic emissions from the active electrode cause manifestation of the modulation in the generator output in the detection circuit.

[0014] In a preferred embodiment the amplitude of the generator output is modulated in a manner such that, in the absence of any thermionic effect, the average value of the generator output as measured over a single cycle of the generator output remains constant: the existence of thermionic emissions causes the average value of the generator output measured over a single cycle to vary at the frequency of the generator amplitude modulation, and the amplitude of this variation in average value corresponds to the extent of the thermionic effect. The detection circuit may be provided by a suitably tuned resonant circuit and a detector which is inductively coupled to the generator output stage to detect a voltage in the resonant circuit which results from thermionic emission.

[0015] The inv ntion will now be described by way of example with reference to the drawings in which:-

Figure 1 is a diagram showing an electrosurgery system in accordance with the invention:

Figure 2 is a fragmentary view of an electrode assembly for tissue ablation, shown in use immersed in a conductive liquid;

Figures 3A and 3B are circuit diagrams of an electrosurgery system including a d.c. offset detector;

Figure 4 is a circuit diagram of an alternative electrosurgery system in accordance with the invention;

Figure 5 is a waveform diagram showing the modulated output voltage waveform of the generator forming part of the system of Figure 4; and

Figure 6 is a waveform diagram showing the generator output waveform in the presence of a thermionic effect at the active electrode of the system illustrated in Figure 4, as well as the average output voltage averaged over single radio frequency cycles of the output voltage.

[0016] The present invention is applicable to both wet and dry field electrosurgery. Referring to Figure 1, the system comprises a generator 10 having an output socket 10S which provides a radio frequency (r.f.) output for an electrosurgical instrument in the form of a handpiece 12 via a connection cord 14. Activation of the generator may be performed from the handpiece 12 via a control connection in cord 14 or by means of a foot switch unit 16, as shown, connected separately to the rear of the generator 10 by a foot switch connection cord 18. In the illustrated embodiment, foot switch unit 16 has two foot switches 16A and 16B for selecting a desiccation mode and a vaporisation mode of the generator respectively. The generator front panel has push buttons 20 and 22 for respectively setting desiccation and vaporisation power levels, which are indicated in a display 24. Push buttons 26 are provided as alternative means for mode selection.

[0017] Handpiece 12 mounts a detachable electrode assembly 28 having a dual electrode structure, as shown in the fragmentary view of Figure 2.

[0018] Figure 2 is an enlarged view of the distal end of the electrode assembly 28. At its extreme distal end the assembly has an active electrode 30 which, in this embodiment, is formed as a coiled wire connected to a central conductor 32. The coil wire may be made of platinum. Proximally of the active electrode 30 and spaced from the latter by a longitudinally and radially extending ceramic insulator 34 is a return electrode 36. The return electrode 36 is arranged coaxially around the inner con-

a direct current between the target tissue and the return electrode is avoided.

[0026] Conversion of the d.c. offset voltage to an alternating signal in the VCO 78 allows a signal representative of the offset voltage level to be transmitted to an isolated control circuit (not shown) connected to the output 80 of the detector via an opto-isolator 82. An indication of the d.c. offset is thus communicated across the safety isolation barrier between the output terminals of the generator and the power generating and control circuitry. In the control circuitry, the alternating signal can be converted back to a d.c. level using a monostable and low pass filter, or may be counted by a gated counter and conveyed digitally. In either case, the control circuitry is arranged to reduce the voltage of source 60 when the d.c. offset voltage reaches a predetermined value (typically within the range 50 to 100 V). In this way, by s lecting a threshold d.c. offset voltage related to the maximum safe operating temperature of the active electrode, the r.f. power delivered to the active electrode can be maximised in different thermal dissipation conditions.

[0027] When the bipolar electrode assembly shown in Figure 2 is used incorrectly, for example when there is insufficient saline around the assembly, it is possible for arcing to occur at the return electrode 36. In such circumstances, the d.c. offset polarity reverses so that the return terminal 64 becomes negative with respect to the active terminal 64 becomes negative with respect to the return. The detector illustrated in Figure 3A includes a reverse polarity detection circuit in the form of a comparator 84 bypassing the VCO 78 and having an output coupled to one input of, for instance, an OR-gate 86 the other input of which receives the alternating output from the VCO 78. The other input of the comparator 84 is coupled to a negative voltage reference. Normally, the output of comparator 84 is low, which means that the alternating signal developed by the VCO passes through OR-gate 84 to the opto isolator 82. However, wh n the d.c. offset voltage on output terminal 64 of the g nerator turns negative by more than an amount dep nding on the negative reference voltage applied to comparator 84, the output of comparator 84 becomes high and OR-gate 86 blocks the alternating signal from the VCO 78, and the lack of an alternating signal applied to the control circuit from the detector output 80 can be used as a fault indication to shut off the r.f. voltage source 60.

[0028] In this embodiment, power for the buffer 76, VCO 78, comparator 84, and OR-gate 86 is derived from the r.f. voltage itself delivered to the output terminals 64 and 66 of the generator, avoiding the need for a further isolation barrier. A suitable power supply for this purpose is illustrated in Figure 3B. A step-down transformer 90 coupled between the output terminals 64 and 66 of the generator drives a bridge rectifier 92 to deliver a d.c. voltage at power supply output terminals 94 across a smoothing capacitor 96. Connection of the secondary winding of the transformer 90 with a centre tap to the return output terminal 66 and thus the common rail of the detector allows buffer 76 to be provided with a dual-polarity supply in order to accommodate positive and negative-going d.c. offset voltages. The fact that deriving power from the r.f. output in this way results in the detector being inoperative at low voltages is no disadvantage since the thermionic effect relied upon as the control stimulus does not occur until the r.f. output voltage of the generator reaches a level consistent with arcing at the active electrode.

[0029] Reference is now made to Figure 4, which diagrammatically shows an alternative generator 110 in accordance with the invention, connected to an electrosurgical instrument having an active electrode 130 and a return electrode 136. The output stage of the generator includes a pair of coupling capacitors 162, 163 which prevent the passage of DC currents between the radio frequency source and the electrodes 130, 136 via the generator output terminals 164, 166. In addition, the generator output stage includes an inductor 168 in series with the active and return electrodes 130, 136 respectively.

[0030] Referring to Figure 5, the output amplitude (i.e. the peak-to-peak output voltage at the output terminals 164, 166) of the generator is modulated, and in the present example a generator output signal is provided, having an output frequency of 500 kHz and amplitude modulated at a frequency of 25 kHz. Naturally, other generator and modulation frequencies may be employed. In the absence of any thermionic effect at the active electrode 136, the generator output voltage is symmetrical about the zero voltage line, i.e. because over a single time period of the generator output, an increase on the value of maximum positive output voltage with respect to the zero reference voltage is matched by a corresponding increase in maximum negative output voltage, the average value of the generator output signal as measured over a single modulation cycle of the generator output is constant.

[0031] However, once sufficient heating has occurred at the active electrode to cause thermionic emission of electrons from the active electrode, there is a net flow of electrons from the active electrode to the return electrode. There is, therefore, a net flow of current from the return electrode (which acts as the anode) to the active electrode (since the direction of current flow is defined as the flow of positive charge). Referring now to Figure 6, this has the effect of shifting the modulated generator output voltage waveform in one direction, here the positive direction, so that rather than having an output voltage the average of which over a single cycle is constant at zero volts in a non-linear manner, the thermionic effect at the electrodes causes partial rectification of generator output and the average output voltage measured over a single cycle is now a non-zero voltage. The magnitude of this voltage varies at the frequency of the amplitude modulation (which in the present example is 25 kHz). This variation in aver-

voltmeter 190 detects the instantaneous depth of the modulation in the generator output, and this may be used to provide a modulation reference by means of which the output from the voltmeter 176 of the sensing circuit may effectively be normalised to reflect only the effect of the thermionic emissions at the electrode 130.

[0039] Use of the invention is not restricted to wet field (underwater) electrosurgery. Arcing also occurs with monopolar or bipolar electrosurgery instruments in dry field surgery and power can be controlled using the thermionic effect in the same way as described above. It is also possible to set the d.c. offset threshold voltage at a comparatively low level in order substantially to avoid nerve stimulation in situations where the active electrode intermittently contacts tissue.

[0040] In monopolar applications the intensity of arcing is dependent on the impedance of the conduction path between the arc site and the return electrode, low imp dance increasing peak arc currents and hence temperature, cutting rate and nerve stimulation. It follows that controlling power according to electrode temperature (so as to reduce variation in electrode temperature) using thermionic effect sensing allows more consistent tissue action to be achieved. This can result in increased cutting quality, for instance, in that tissue damage and char formation adjacent the cutting site can be reduced compared with electrosurgical action relying on voltage control alone.

[0041] Thermionic feedback in an electrosurgical generator offers a number of benefits, including achieving increased tissue ablation and cutting rates, potentially reducing damage to adjacent tissue, and adjacent char formation, as well as reduced nerve stimulation.

[0042] Using the thermionic effect occurring in the presence of arcing at an electrode as the stimulus of a feedback mechanism, as described in this specification, allows electrosurgery to be performed at relatively high power densities substantially without electrode damage. Thus, using a high melting point material such as platinum, very high tissue cutting and tissue removal pow r densities may be achieved or, for a given power density, comparatively inexpensive, low melting point metals or alloys may be used with safety (e.g. stainless steel). The described system may also be used to reduce the possibility of electrode misuse and consequent electrode damage. The ability to maintain large arcs lessens the possibility of contact of the active electrode with tissue, therefore decreasing the possibility of nerve stimulation.

[0043] While the preferred embodiments of the invention are systems in which the thermionic effect is sensed by means of a circuit within an electrosurgical generator unit, i.e. within the casing of such a unit, it is possible to embody the invention in an add-on module coupled in the conduction paths between the output terminals of the generator unit and the electrosurgical instrument. The module may have its own connector which fits into the socket 10S of the generator unit and a socket for receiving a plug assembly on the connection cord 14 shown in Figure 1. Circuitry for detecting an offset voltage is contained within the module, connected to lines forming the conduction paths between the generator unit and the instrument, and the transmission of electrosurgical power to the instrument controlled by means of a variable impedance element within the module or by feeding a control signal to a control input of the generator unit. For the avoidance of doubt, the combination of an add-on module of this description and a separate generator unit are considered to constitute an electrosurgical generator within the scope of the present invention as claimed.

[0044] Although the described embodiments perform a control function in that generator output power is controlled or regulated in response to the sensed thermionic effect, the invention includes within its scope a system in which the means for sensing thermionic emissions are used simply as an indicator of electrode temperature, e.g. for providing a temperature readout for the surgeon.

Claims

1. An electrosurgery system comprising a generator which includes a source of radio frequency (r.f.) energy for feeding to a treatment electrode of an electrosurgical instrument, wherein the generator includes a circuit for sensing thermionic emission from the electrode.

2. A system according to claim 1, wherein the generator includes a control circuit operable to control the r.f. energy fed to the treatment electrode in response to an output signal from the sensing circuit, the sensing circuit and control circuit being arranged to reduce the applied r.f. energy as thermionic emission from the electrode increases.

3. A system according to claim 1 or claim 2, wherein the sensing circuit has an input stage arranged substantially to remove r.f. signals at the operating frequency or frequencies of the generator to yield an averaged representation of the r.f. output of the generator, and a detection stage coupled to the input stage to receive the averaged representation.

4. A system according to any preceding claim, wherein the generator has an output terminal for connection to the treatment electrode, and wherein the sensing circuit is arranged to detect at the output terminal d.c. voltages within a predetermined voltage range lying above 2 volts.

5. A system according to claim 4, wherein the sensing circuit is arranged to generate a threshold signal when the detected d.c. voltage exceeds predetermined threshold value.

detector includes a power supply circuit connected between the said active and return terminals and including a rectifier for rectifying an r.f. electrosurgery signal applied across the output terminals.

24. A generator according to claim 22 or claim 23, wherein the detector includes an oscillator for generating an alternating measurement signal representative of the d.c. offset, and wherein the isolation device comprises an opto-isolator coupled to receive the alternating measurement signal and to feed it to the control circuit.

25. A generator according to any of claims 19 to 24, wherein the detector includes a reverse d.c. offset detection circuit allowing detection of both (a) a positive d.c. offset greater than a predetermined voltage value and (b) a negative d.c. offset on the active output terminal.

26. A generator according to any of claims 22 to 24, wherein the detector has an input circuit coupled to the generator output terminal, which input circuit includes a r.f. choke and a series resistance of at least 2MΩ.

27. A method of performing electrosurgical tissue cutting or ablation in which radio frequency (r.f.) energy is applied to an electrosurgical instrument so as to promote arcing at a treatment electrode of the instrument, the level of such energy being regulated according to the level of thermionic emission from the electrode.

28. A method according to claim 27, wherein the r.f. energy is regulated to maximise the temperature of the electrode without substantial electrode burning.

29. A method according to claim 27, wherein the r.f. energy is regulated to limit the d.c. voltage to a threshold value of less than 100V.

30. An electrosurgical generator comprising a radio frequency (r.f.) power source operable at a generator operating frequency, and an output stage including a pair of r.f. power output terminals, the output stage being DC-isolated from the source, the generator further comprising means for modulating the r.f. power signal generated by the source, and a sensing circuit AC-coupled to and DC-isolated from the output stage and operable to generate an averaged AC signal containing a modulation component representative of a DC shift in the power signal delivered to the output terminals.

31. A generator according to claim 30, wherein the modulation means produces amplitude modulation in the r.f. power signal at a predetermined modulation frequency, and wherein the generator further comprises a filtering element associated with the sensing circuit for substantially removing an r.f. component at the operating frequency from the input to the sensing circuit to yield the averaged AC signal.

Fig. 2

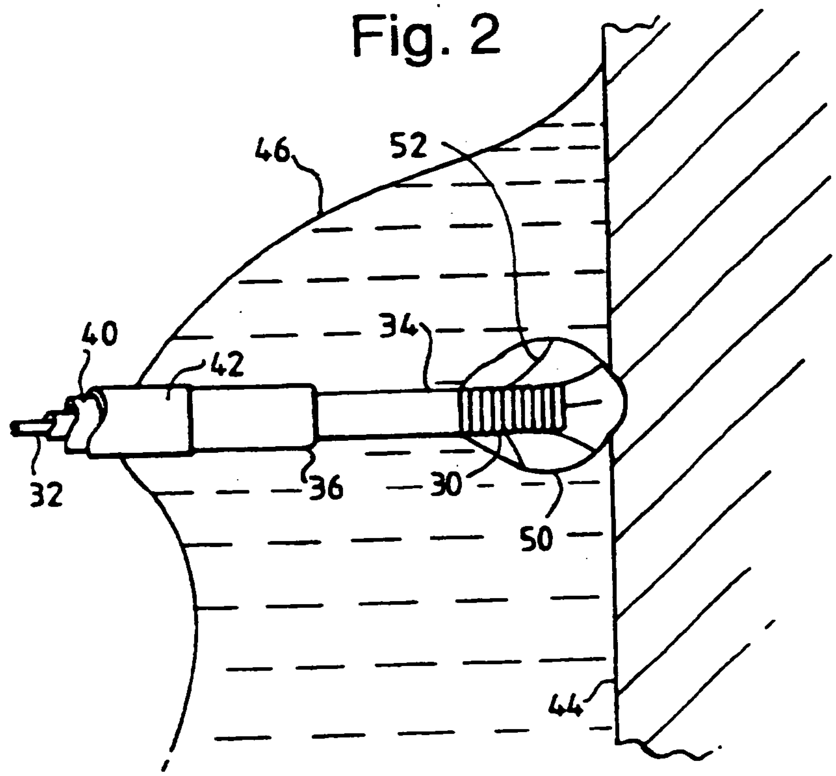
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Fig. 4

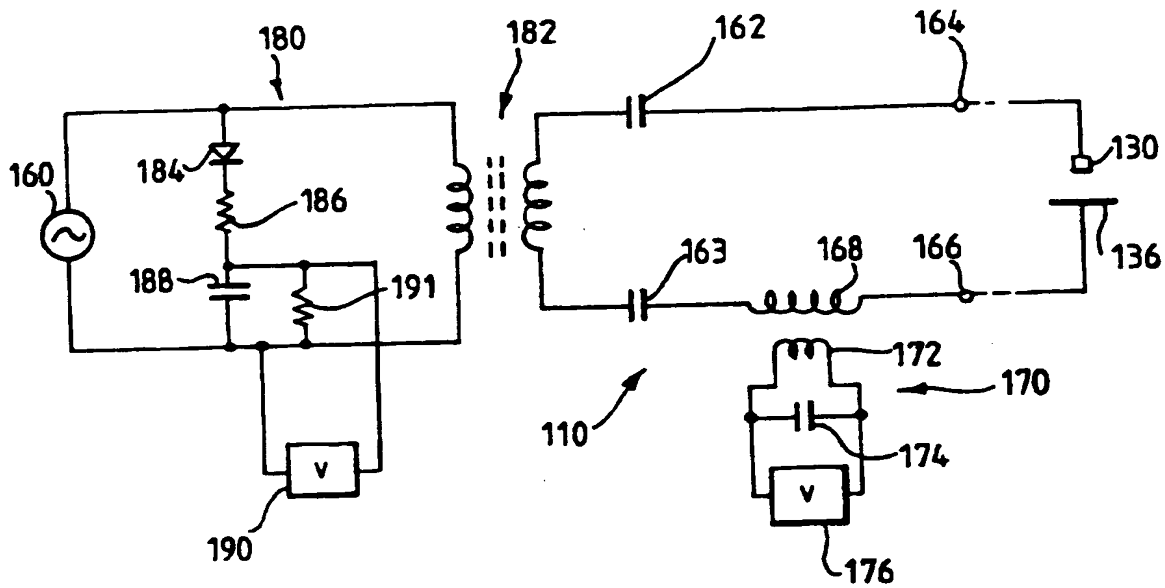
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Fig. 5

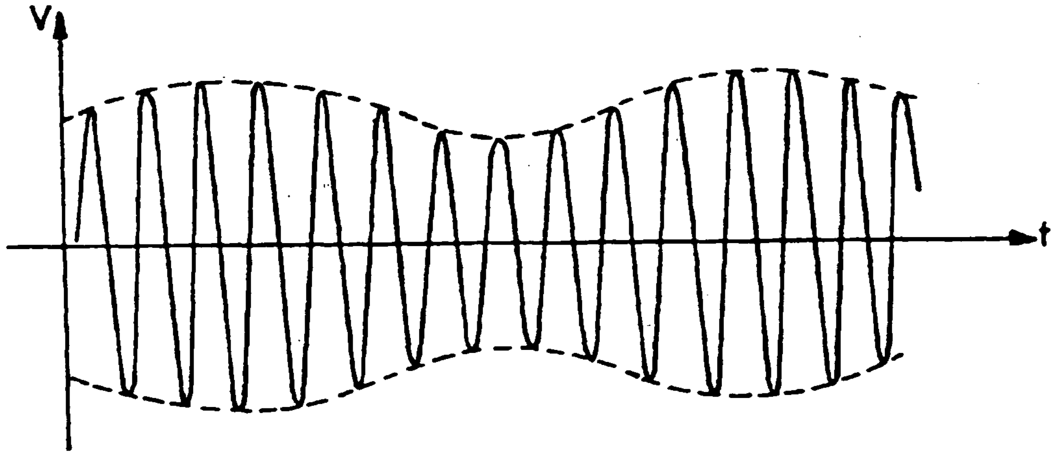
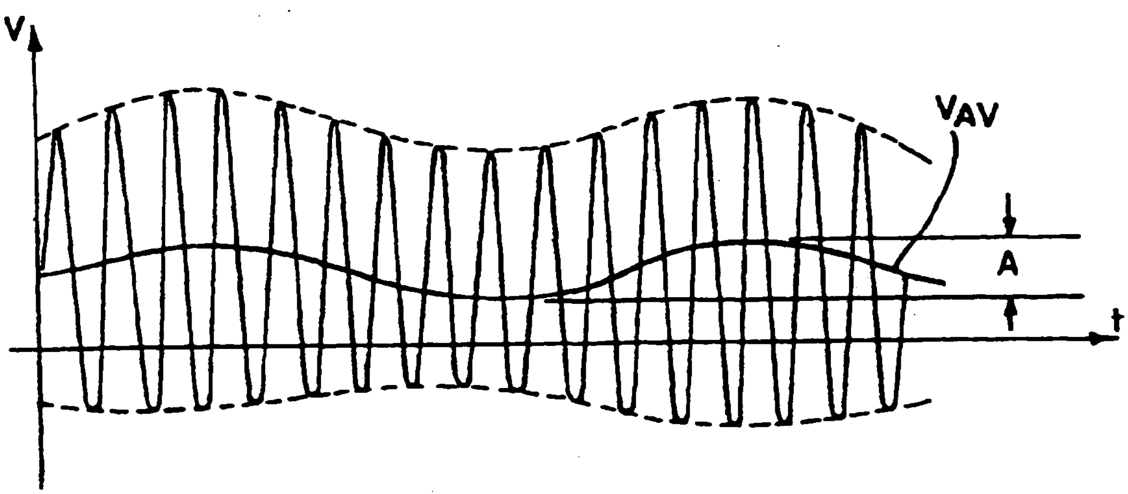


Fig. 6



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